J845-EP-3

(12) UK Patent Application (19) GB (11) 2 350 740 (13) A

(43) Date of A Publication 06.12.2000

(21) Application No 8617962.9

(22) Date of Filing 23.07.1986

(51) INT CL[7]
G01S 7/35 13/34

(52) UK CL (Edition R)
H4D DRPN DSPB D265 D393 D411 D417

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition I) H4D
INT CL[4] G01S

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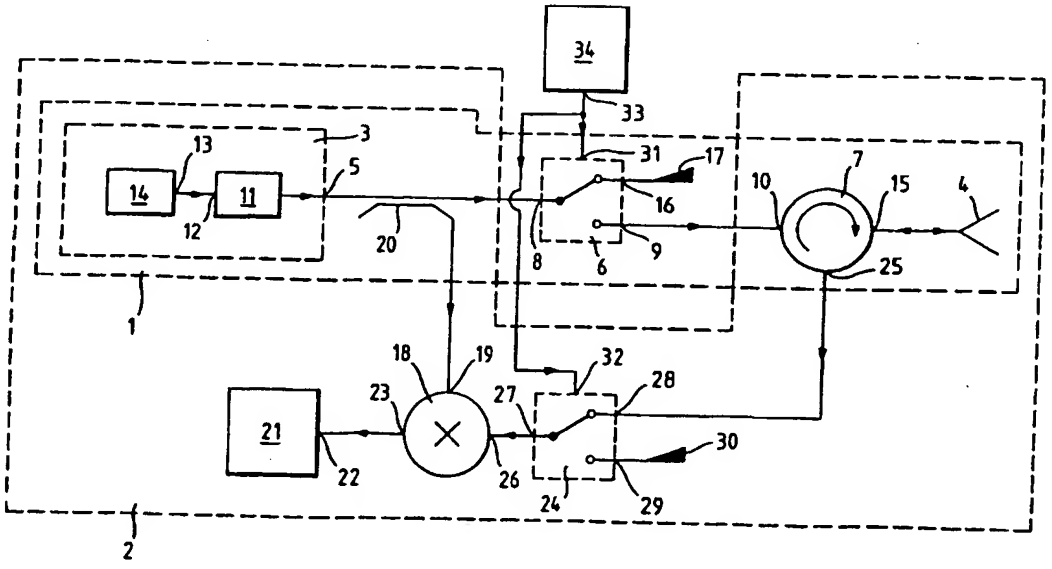
(54) Abstract Title
Radar apparatus

(57) A radar apparatus comprises a transmitter section 1 and a receiver section 2 which are enabled and disabled alternately in antiphase by means of controllable switches 6, 24 in order to prevent direct breakthrough from the transmitter section into the receiver section. This process creates "blind" ranges for which the instants of reception of the received signal coincide exactly with instants during which the receiver section is disabled. In order to provide a reasonably flat sensitivity-versus-range characteristic between these ranges the switches are controlled by the output of a pseudo-random signal generator 34.



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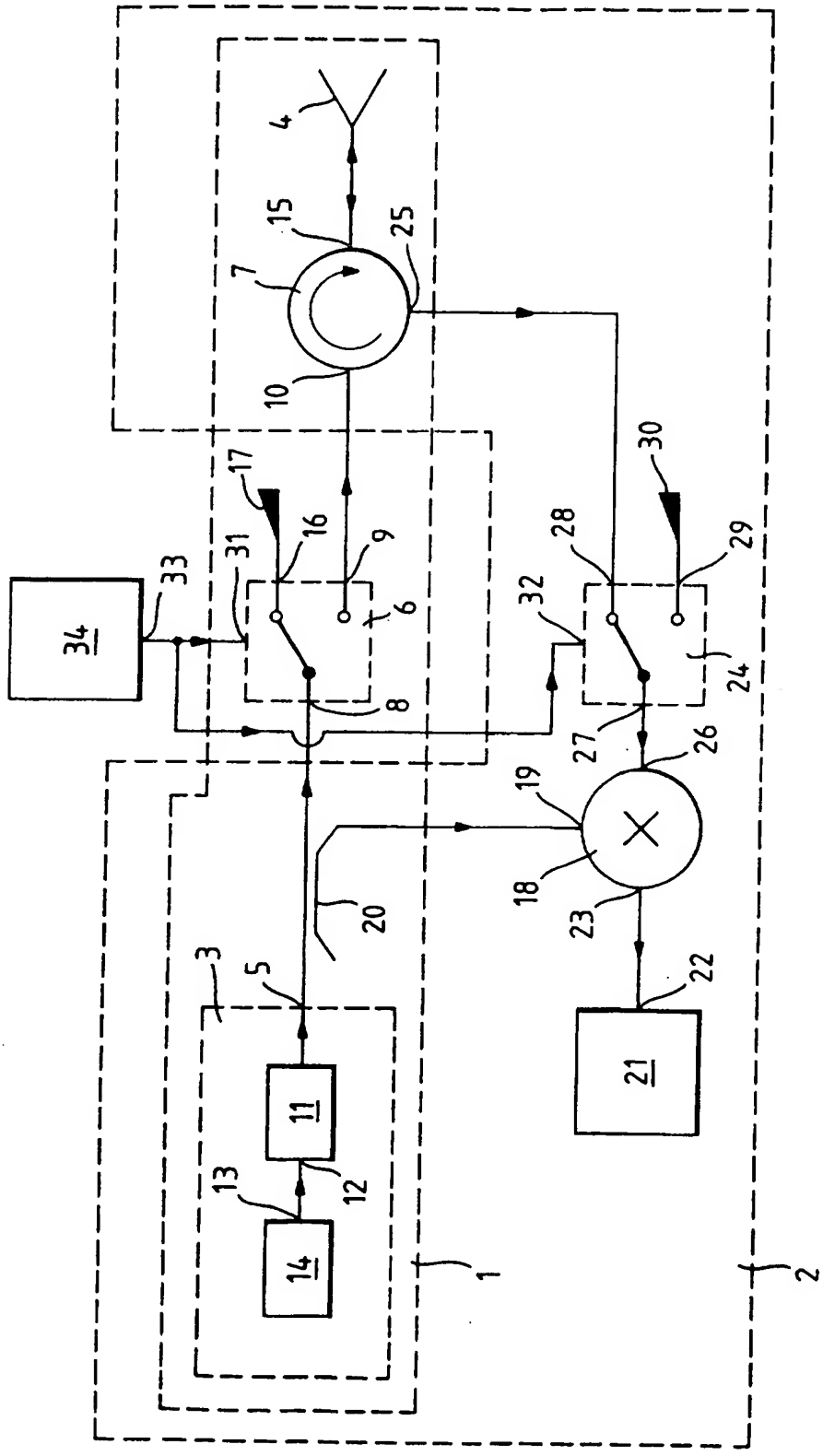
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.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RADAR APPARATUS

This invention relates to a radar apparatus comprising a transmitter section for transmitting an electromagnetic wave, a receiver section for receiving any of the transmitted wave reflected thereto by a target, and means for alternately enabling and disabling the transmitter section for transmission of said electromagnetic wave and alternately enabling and disabling the receiver section for reception of the reflected said electromagnetic wave in such manner that the reception is always disabled for the whole of those periods during which the transmission is enabled and is enabled during those periods when the transmission is disabled.

Radar apparatuses essentially comprise a transmitter section for transmitting an electromagnetic wave and a receiver section (possibly using the same aerial) for receiving any of the transmitted electromagnetic power reflected thereto from a target. It is a recognised problem with such apparatuses that, because the transmitted power is so much greater than the reflected power reaching the receiver, it is difficult to prevent a portion of the transmitter output power which is significant relative to the received reflected power leaking directly into the receiver, which can degrade the receiver performance or actually damage the receiver. A solution to this problem, as far as so-called "continuous-wave" radars are concerned, known from pages 367-371 of the book by F.E. Nathanson entitled "Radar Design Principles" (McGraw-Hill, New York 1969), is to disable the transmitter and receiver alternately at a fixed rate, e.g. by connecting them to respective antennas or to a combined transmit/receive antenna alternately, but never at the same time, the best switching duty cycle being 50 per cent each for both transmitter and receiver. However this has the disadvantage that the radar sensitivity-versus-range characteristic then takes the form of a regular triangular wave (of decreasing amplitude), with each minimum corresponding to zero sensitivity. This is

because the radar becomes completely "blind" to targets whose range r satisfies r=ncT/2, where T is the period of the transmitted pulses, n is an integer, and c is the velocity of light, because in such a case a pulse reflected from the target will arrive at the receiver during exactly a time when another pulse is being transmitted, i.e. while the receiver is disabled. The sensitivities at intermediate ranges are governed by what the corresponding degree of overlap is between the received reflected pulse and the current disablement period of the receiver, this overlap, for a 50 per cent switching duty cycle, being zero for ranges r which satisfy r=(n+1/2)cT/2 and varying linearly with range between these ranges and the adjacent ranges which satisfy r=ncT/2. It is an object of the invention to enable the form of the sensitivity-versus-range characteristic for the said intermediate ranges to be improved.

The invention provides a radar apparatus comprising a transmitter section for transmitting an electromagnetic wave, a receiver section for receiving any of the transmitted wave reflected thereto by a target, and means for alternately enabling and disabling the transmitter section for transmission of said electromagnetic wave and alternately enabling and disabling the receiver section for reception of the reflected said electromagnetic wave in such manner that the reception is always disabled for the whole of those periods during which the transmission is enabled and is enabled during those periods when the transmission is disabled, characterised in that said means includes a pseudo-random signal generator and is arranged to enable and disable said transmission and reception under the control of the output signal of said generator.

It has now been recognised that that component of the sensitivity-versus-range characteristic of the radar which is produced by chopping the transmitted wave and enabling reception for its reflections during each period when there is no transmission is equal to one minus the autocorrelation function of the chopping waveform. Thus, ideally, a chopping waveform

should be chosen whose autocorrelation function is substantially zero for all values of delay, i.e. a chopping waveform which is completely random in nature. Production of such a chopping waveform is, however, not practicable. On the other hand, the well-known pseudo-random signal generators produce a two-level signal at a steady clock rate, which one of the two levels the signal takes during each successive clock period being apparently random, although in fact these levels from a repeating sequence the length of which is determined by the particular construction adopted. The autocorrelation function of such a signal is equal to unity at values of delay which correspond to multiples of the sequence duration, but between these values it drops rapidly to a very low level. Thus adoption of the output signal of such a generator as a chopping waveform results in the shape of the radar sensitivity-versus-range characteristic being substantially unaffected by the chopping, except for ranges at and close to values corresponding to multiples of the pseudo-random sequence length. The resulting characteristic is much nearer the ideal (flat) characteristic than is the triangularly-varying characteristics obtained when the transmitted wave is chopped at a constant rate.

In order to obtain maximum sensitivity said means is preferably arranged to enable the reception for substantially the whole of each period during which the transmission is disabled.

Conveniently the transmitter section may comprise a generator for a radio-frequency signal and a first coupling from an output of said generator to an aerial, which coupling includes a first switch, the receiver section may comprise a signal processing section and a second coupling from an aerial to an input of said signal processing section, which coupling includes a second switch, and the output of the pseudo-random signal generator may be coupled to control inputs of these switches for controlling these switches in antiphase. Preferably a band-pass filter is then included in the second coupling prior to the second switch, the bandwidth of which filter is less than

in the known apparatus. However, in contrast to the known apparatus the switches 6 and 24 do not change over at a steady rate, but rather their positions are governed by the repeating pseudo-random sequence produced by the generator 34. As pointed out hereinbefore, this results in the shape of the sensitivity-versus-range characteristic being substantially affected by the chopping only at ranges which substantially correspond to delays equal to integral multiples of the duration of the repeating sequence produced by generator 34, which is much more satisfactory than the repeating triangular characteristic which would be obtained if the chopping were at a steady rate.

In the interests of noise suppression a further chopping device (not shown) operating in phase with switch 24 is preferably provided at the input 22 of signal processor 21.

As is known, with swept-frequency radar of the type described the spectrum of the output signal of mixer 18 (consisting inter alia of components having frequencies equal to the difference between the frequencies of signals received by the antenna 4 and the instantaneous frequency of the output signal of generator 3) contains components the frequencies of which, to a first order, are determined by the rate of change of the frequency of the signal at the generator output 5 and the range of the target from which the signal received by the antenna was reflected. Because the enabling/disabling of the receiver section 2 by means of switch 24 effectively results in sampling of any signal at the port 25 of circulator 7, this rate of change, and the maximum design range of the radar, are preferably such that these frequencies are always less than one half the reciprocal of the duration of the repeating sequence produced by generator 34, in order that the chopping/disabling will not result in unacceptable degradation of the wanted output signal of mixer 18 because of aliassing. In other words, the output frequency and sequence length produced by the generator 34 are preferably chosen sufficiently high that these conditions are satisfied, enabling any resulting aliassing components in the

output signal of mixer 18 to be removed by low-pass filtering, if desired.

In practice amplifiers will, of course, normally be provided in the signal paths from generator 3 to port 10 and from port 25 to processor 21. As far as the signal path from generator 3 to port 10 is concerned it is preferred that the amplifier operates on the chopped signal rather than on the input signal to the switch 6; in fact the chopping may be achieved by switching the power supply to, or otherwise gating, such an amplifier.

Co-pending patent application 86 17760 (PHB33283) of even date in the name of the present applicant describes and claims a method of operating radar apparatuses in which the transmitter section of the apparatus is caused to transmit in time or frequency-multiplexed form (a) an electromagnetic wave chopped at a first rate with a given mark-to-space ratio and (b) an electromagnetic wave chopped at a second rate with a given mark-to-space ratio, the first rate being different from the second rate, and the receiver section of the apparatus is disabled for reception of (a) during the "mark" periods of (a) and is disabled for reception of (b) during the "mark" periods of (b). This is to prevent the apparatus being completely blind to specific ranges for the reason outlined in the preamble of the present application, the blind ranges corresponding to the two different chopping rates being different from each other. An apparatus according to the present invention may, if desired, be operated in a similar way because, as mentioned hereinbefore, the apparatus described with reference to the drawing is blind to ranges for which the time taken for the transmitted wave to traverse a path to and from a target corresponds to an integral multiple of the duration of the repeating sequence produced by generator 34. Thus, for example, the generator 34 may be replaced by a pair of pseudo-random signal generators which produce repeating sequences having different durations, the outputs of these generators being switched to the output 33 alternately, for example in step with the successive frequency

sweeps produced by generator 3. Alternatively, the output frequency of generator 3 may be translated by respective mixers into two non-overlapping frequency bands, the resulting signals being applied to antenna 4 via respective switches similar to switch 6, these being controlled by the output signals of respective pseudo-random signal generators which produce repeating sequences having different durations. A frequency diplexer (not shown) will then have to be provided at port 25 of circulator 7, which diplexer separates out the respective frequency bands and directs them into respective channels each containing a respective switch, similar to switch 24, which is correctly ganged to the switch, similar to switch 6, in the corresponding transmission channel, so that when each transmission channel is enabled the corresponding reception channel is disabled, and vice versa. In other words the fixed frequency generators referenced 39 and 40 respectively in Figures 1 and 2 of the drawings of said copending application may be replaced by respective pseudo-random signal generators the repeating sequences generated by which have different durations.

Another co-pending Patent Application No. 86 17961 (PHB33284) of even date in the name of the present applicant, describes and claims a radar apparatus in which measures are taken to overcome the disadvantage that the duty cycle of a radar apparatus in which the transmitted signal is actually chopped and the receiver channel is enabled/disabled correspondingly to avoid direct break-through is only 50% at most. To this end, instead of actually switching off the transmitted signal each time the receiver is enabled, its frequency is changed to another value. In other words the frequency of the transmitted signal is switched between a pair of values at the chopping rate. The receiver is provided with respective frequency channels corresponding to the two values, each of these being disabled when the corresponding frequency value is being transmitted and being enabled otherwise. Such measures may also be applied, if desired, in an apparatus according to the present invention. To

this end switch 6 may be replaced by a signal path from one input to an output of a mixer the second input of which is fed from respective members of a pair of local oscillators alternately via a changeover switch controlled by pseudo-random signal generator 34, so as to produce the two values of transmitted frequency in a pseudo-random manner. Again a frequency diplexer may then be provided at port 25 of circulator 7, which diplexer directs these two frequencies into respective channels each containing a switch, similar to switch 24, which is also controlled by the output of generator 34 in such a way that it is open when the corresponding frequency is being transmitted and is closed otherwise. The output signals of the switches can then be down-converted in respective mixers and then mixed with the output of directional coupler 57. In other words the fixed-frequency switching signal generator referenced 21 in the drawing of the latter co-pending application may be replaced by a pseudo-random signal generator.

Although the invention has been described with reference to swept-frequency continuous-wave (in fact interrupted continuous-wave) radar apparatuses, it will be evident that it is also applicable to other types of radar apparatuses, for example radar apparatuses of the steady-frequency or effectively steady-frequency continuous wave or interrupted continuous-wave type.

CLAIM(S)

1. Radar apparatus comprising a transmitter section for transmitting an electromagnetic wave, a receiver section for receiving any of the transmitted wave reflected thereto by a target, and means for alternately enabling and disabling the transmitter section for transmission of said electromagnetic wave and alternately enabling and disabling the receiver section for reception of the reflected said electromagnetic wave in such manner that the reception is always disabled for the whole of those periods during which the transmission is enabled and is enabled during those periods when the transmission is disabled, characterised in that said means includes a pseudo-random signal generator and is arranged to enable and disable said transmission and reception under the control of the output signal of said generator.

2. Apparatus as claimed in Claim 1, wherein said means is arranged to enable the reception for substantially the whole of each period during which the transmission is disabled.

3. Apparatus as claimed in Claim 1 or Claim 2, wherein the transmitter section comprises a generator for a radio-frequency signal and a first coupling from an output of said generator to an aerial, wherein the receiver section comprises a signal processing section and a second coupling from an aerial to an input of said signal processing section, wherein said pseudo-random signal generator is arranged to produce a bivalent signal, and wherein said means is arranged to block transmission through said first coupling and enable transmission through said second coupling when the output signal of the pseudo-random signal generator has one of its values and to enable transmission through said first coupling and block transmission through said second coupling when the output signal of the pseudo-random sequence generator has the other of its values.

4. Apparatus as claimed in Claim 3, wherein said means includes first and second controllable switches in said first and second couplings respectively, and couplings from the output of

said pseudo-random signal generator to control inputs of said switches for controlling said switches in antiphase.

5. Apparatus as claimed in Claim 4, including a band-pass filter in said second coupling prior to said second switch, the bandwidth of which filter is less than one-half the reciprocal of the duration of each repeating sequence generated by said pseudo-random signal generator.

6. Apparatus as claimed in Claim 3, 4 or 5, wherein the generator for a radio-frequency signal comprises a controllable-frequency oscillator and a frequency control signal generator an output of which is coupled to a frequency control signal input of said oscillator for periodically sweeping the frequency of said oscillator between first and second values.

7. Radar apparatus substantially as described herein with reference to the drawing.

EXAMINER'S REPORT TO THE COMPTROLLER
UNDER SECTION 17(5)
(The Search Report) 12

FIELD OF SEARCH: The search has been conducted through the relevant published UK patent specifications and applicatic applications published under the European Patent Convention and the Patent Co-operation Treaty (and such other documents be mentioned below) in the following subject-matter areas:-

UK Classification H4D (DRPL, M, N, P, Q, R, S; DSX)

(Collections other than UK, EP & PCT:) Selected US specifications classified in IPC sub class G01S

DOCUMENTS IDENTIFIED BY THE EXAMINER (NB In accordance with Section 17(5), the list of documents below may i only those considered by the examiner to be the most relevant of those lying within the field (and extent) of search)

Category	Identity of document and relevant passages	Relevant to cla
	NONE	

CATEGORY OF CITED DOCUMENTS

X relevant if taken alone
Y relevant if combined with another cited document
P document published on or after the declared priority date but before the filing date of the present application
E patent document published on or after, but with priority date earlier than, the filing date of the present application

Search examiner
H E GRIFFITHS

Date of search
6 March 1987